This article was downloaded by: [University of Sydney]
On: 02 May 2015, At: 10:58
Publisher: Routledge
Informa Ltd Registered in England and Wales Registered Number: 1072954
Registered office: Mortimer House, 37-41 Mortimer Street, London W1T 3JH, UK

Royal United Services Institution. Journal

Publication details, including instructions for authors and subscription information:

<http://www.tandfonline.com/loi/rusi19>

On Submarine Boats

Thorsten Hordenfelt Esq

Published online: 11 Sep 2009.

To cite this article: Thorsten Hordenfelt Esq (1886) On Submarine Boats, Royal United Services Institution. Journal, 30:133, 149-173, DOI: [10.1080/03071848609416367](https://doi.org/10.1080/03071848609416367)

To link to this article: <http://dx.doi.org/10.1080/03071848609416367>

PLEASE SCROLL DOWN FOR ARTICLE

Taylor & Francis makes every effort to ensure the accuracy of all the information (the "Content") contained in the publications on our platform. However, Taylor & Francis, our agents, and our licensors make no representations or warranties whatsoever as to the accuracy, completeness, or suitability for any purpose of the Content. Any opinions and views expressed in this publication are the opinions and views of the authors, and are not the views of or endorsed by Taylor & Francis. The accuracy of the Content should not be relied upon and should be independently verified with primary sources of information. Taylor and Francis shall not be liable for any losses, actions, claims, proceedings, demands, costs, expenses, damages, and other liabilities whatsoever or howsoever caused arising directly or indirectly in connection with, in relation to or arising out of the use of the Content.

This article may be used for research, teaching, and private study purposes. Any substantial or systematic reproduction, redistribution, reselling, loan, sub-licensing, systematic supply, or distribution in any form to anyone is

expressly forbidden. Terms & Conditions of access and use can be found at <http://www.tandfonline.com/page/terms-and-conditions>

Friday, February 5, 1886.

MAJOR-GENERAL SIR ANDREW CLARKE, G.C.M.G., C.B., C.I.E.,
Inspector-General of Fortifications, &c., in the Chair.

ON SUBMARINE BOATS.

By THORSTEN NORDENFELT, Esq.

WHEN the Council of this Institution did me the honour to call upon me to read this lecture, I felt considerable hesitation how to deal with the subject, as it covers too large a ground for one single lecture. I, however, came to the conclusion that I should best meet the wishes of the members by stating what has been done, and what is being done in this direction, and by giving my views upon what can and what cannot be done by submarine boats in practical warfare; and not to encumber the lecture with too many technical and scientific details, as these would form sufficient material for a separate lecture, which might perhaps more properly belong to the Naval Architects or other scientific institutions.

First, I beg to be allowed to say that I cannot admit, as I have heard stated, that there is anything especially cruel or horrible in the idea of a submarine boat.

War altogether is cruel and horrible, and causes an enormous amount of pain and suffering, but any invention which may tend to shorten a war, or to protect commerce and private property during war, will really diminish this suffering on the whole.

It has been said that there is something especially cruel in the fact that a submarine boat advances in secrecy, and without giving the opponents any chance of firing at it or of protecting themselves against it, but the whole tendency of war has moved in this direction, ever since the days of old, when Hector and Achilles advanced in front of their respective followers, and spent half-an-hour in abusing their adversary's parents and ancestors before they commenced to fight.

What can be more cruel than the leaden bullet which kills at the distance of a mile when you cannot see either the rifle or the man who fires the bullet; or the shell from a 100-ton gun, which may

cause the destruction of a large vessel six miles from shore if it strikes a vital part?

A fish torpedo is a secret missile, and hitherto every naval architect has done his utmost to render it more effective by increasing the speed of the surface torpedo-boats, and thereby make the attack more sudden and unexpected. If I have gone a step further by carrying the torpedo under water up to the point where it can be most effectually discharged, I have made the attack still more sudden and unexpected, but I have at the same time increased the chances of safety for the crew of the torpedo carrier, who in a surface boat are as much exposed as was the light brigade which charged the Balaclava batteries.

The same secrecy or suddenness of attack is permitted ashore; the whole object of strategy is to keep the enemy ignorant or to mislead him as to the movements of an army until the General can deliver a sudden attack by overwhelming forces, and an ambush is nothing but the development of this idea. Sir Andrew Clarke, and other leaders of modern engineering, are now averse to the heavy granite structures which offered a long range target for the enemy's ship, and do their utmost to assimilate the appearance of the batteries to the surrounding country by covering the earth with turf and shrubs; the latest development of which idea is the revival in another shape of Moncrieff mountings by the present Inspector-General of Fortifications in the disappearing gun platform which can be laid against the enemy's ship before the heavy gun suddenly appears out of a peaceful looking ploughed field, discharges its deadly projectile, and again disappears through its trap-door, after having shown itself for a few seconds only.

The principal *raison d'être* of a submarine boat is the suddenness of its attack, and if the attack by torpedoes fired from a submarine boat is more effective than that fired from a surface boat, while the crew is less exposed in the submarine boat, it should find its place amongst the armaments of nations.

The submarine boat is and must always remain essentially a means of defence, and when ports can be defended by submarine boats against bombardments and blockades, even if their action were cruel and horrible, the enemy can best avoid any suffering from their action by refraining from attacking the ports of my country, and then my object would be gained.

The idea of submarine boats is very old. The first record I have found of such a boat is the one which was built by David Bushnell during the American War of Independence.

As early as 1776 this boat was used in an attempt to blow up the English man-of-war the "Eagle;" it, however, failed to do so, and there was a strong suspicion, when the man who undertook the task returned to shore the next morning to claim his reward, that he had never seriously tried, but had passed his night comfortably floating on the water.

Washington, in a letter to Jefferson, in 1785, wrote that it was difficult to find men to undertake the risk of making an attack with

this entirely novel invention in consequence of the difficulty of driving and steering it under water, and the uncertainty of attaining its object.

It was not a comfortable boat, its appearance was that of two turtle-backs screwed together, its crew consisted of only one man, who had air enough for thirty minutes, during which time he had to work by hand the screw which propelled the boat, to pump in and out water by hand for descending to desired depths, and to let go 200 lbs. of ballast for rapidly rising to the surface.

The explosive mine contained 150 lbs. of powder, and was to be screwed into the bottom of the enemy's wooden vessel, after which the charge was exploded by clockwork started by the operator when he retired after having fixed his mine.

This of course sounds very crude, still it contained the germs of nearly all the subsequent unsuccessful attempts to make efficient submarine boats.

Next came Robert Fulton, who tried a submarine boat, also propelled by hand, at Brest, in France, where he remained under water for one hour. As the French Government did not adopt his invention, Fulton went in 1784 to England, where Pitt showed considerable interest in his invention, and some very costly experiments were carried out with his submarine boat as well as with his surface torpedoes, which, however, did not lead to any results.

Fulton then returned to his native land, and the United States Government paid for serious attempts to develop his inventions, without success, however, as far as the submarine boat was concerned.

In 1821, an Englishman, Johnson, built a submarine boat on the Thames, which turned out a failure altogether. I have not been able to find any details of the construction of this boat.

Nothing more was heard of submarine boats until 1851, when a Bavarian, by name of Bauer, constructed a submarine boat for the Holsteiners to use against the Danish war-ships which blockaded Kiel. It was not, however, completed in time, and did not give satisfaction when ready. It was propelled by hand, with pumps for changing the specific gravity of the boat, and a special apparatus with watertight gloves, for fixing under the vessel a mine which was to be fired by electricity. At the final trial the boat sank right enough, but could not be raised.

About the same time a Frenchman called *Alexandré* had some trials in New York Harbour with a submarine boat, but it does not seem to have offered any new feature.

At the time of the Crimean War, the Russians, according to subsequent reports in the English press, used a sort of submarine mine which could be moved a certain distance, but which could hardly be called a boat. A full description was given of this in the "Illustrated London News" for the 23rd June, 1855.

Two explosions were said to have taken place under H.M.S. "Merlin," off Cronstadt, the shocks of which caused considerable alarm on board, without, however, doing much damage. This

movable mine was probably some modification of Dr. Payerne's movable diving bell which was tried in 1847 in Paris and Cherbourg, and which was described in "*La Presse*," in 1847.

During the War of Secession in the United States, the attention of both sides was drawn to submarine boats. The Northern Government, anxious to destroy the Southern ironclad "*Merrimac*," arrested to have agreed to pay a Frenchman 10,000*l.* for his invention of a submarine boat, with a further sum of 5,000*l.* for each successful attack. The first-named sum seems to have been paid, but the boat was never successfully built.

The Confederate authorities carried the point further, and actually sank one or two Northern vessels by means of such boats. The first boat, made of thin iron plates, was 35 feet long, 3 feet beam, and 5 feet deep; she was propelled by hand by eight men, who worked a longitudinal shaft, which, by gearing, gave a considerable number of revolutions to her screw. Her greatest speed was 4 knots in smooth water; the air-space in her was said to be sufficient for the eight men and the captain for two hours. Two side rudders were used for sinking and raising the boat when in motion, and its depth was supposed to be regulated by the incline given to these rudders; when not moving, the boat was sunk and raised by taking in and pumping out water. The boat was meant to tow a mine which would explode on contact with the enemy's vessel; but when this boat sank the Federal vessel "*Housatonic*," in February, 1864, she used a spar torpedo; the great danger of this was proved by her going down, with her crew of nine men, together with the ship she destroyed. The Federal flagship "*Harvest Moon*," Admiral Dahlgren, was also sunk by a mine; but though the Continental press at the time stated that this mine was carried by a submarine boat, other reports say that it was a fixed ground mine.

At the Paris Exhibition, 1867, another submarine boat was shown, designed by Admiral Bourgois and Mr. Brune. She was 26 feet long and 9 feet deep; her screw, worked by four men, was said to give her 4 knots speed; she also descended and ascended by means of water being taken in and pumped out. Secret experiments are said to have been made with this boat by the French Government.

The Russian Government has for years spent large sums of money upon the perfection of submarine boats. In 1868 a boat, built of the so-called "*Alexandrofsky*" type, was run on the Neva, off Mr. Winans' railway works; she was towed by a steam launch and descended successfully several times, but did not seem to satisfy the Russian naval authorities.

About five years ago another submarine boat, made on what is called the "*Bjervalsky*" system, was tried in St. Petersburg. I have not seen any other details given of her than that she is 20 feet long, and is propelled by a screw worked by four men; that she descends and ascends by increasing and diminishing her water ballast; she is said to be held in horizontal position by shifting the water ballast longitudinally fore and aft; air is supplied through chemical means to keep her crew under water up to nine hours. She is said to have

often descended to a depth of 15 feet, and her speed is 3 knots. A considerable number of these "Bjevalskys" are reported to have been built for coast defence in Russia.

The "Engineering," of 20th November, contains a very full description of the "Goubet" system of submarine boat, a large number of which are said to have been ordered by the Russian Government. This description seems very like what in Russia is called the "Bjevalsky" system, though the "Goubet" boat requires only two men. The "Goubet" boat descends and ascends by taking in and pumping out water, in addition to which a heavy weight can be dropped if it is necessary to rise to the surface more quickly than by pumping out water. The mine contains 110 lbs. of dynamite, and when the submarine boat has reached a position directly underneath the enemy's vessel the mine is cast off and rises through its floatability, when it is meant to attach itself to the bottom of the vessel by means of a ring of spikes; this done, the submarine boat retires to a safe distance and the mine is fired electrically through a connecting wire.

It is intended to apply electrical motive power to this boat by accumulators; but the constructors do not seem to place much faith in this, as they have applied oars to be used if or when the electrical motors fail.

Mr. Garrett designed a submarine boat some ten years ago, and one was built by Messrs. Cochrane, of Liverpool. This boat was 45 feet long, of the shape of two cones, with a central cylindrical portion. It descended by means of pistons which varied the displacement of the boat by being drawn in and pushed out, as well as by central rudders which steered it up and down like the Confederate boat. Compressed air as well as chemical compounds were carried to give air to the crew. This boat was never applied to war purposes, but after a number of experiments it was lost off the Welsh coast, and I have had much advantage of the negative experience gained during those experiments in avoiding the faults which made that boat unsuccessful.

The idea seems throughout to have been admitted that submarine boats, if successful, would become most valuable and comparatively inexpensive weapons for port defence; but none of the boats so far have given satisfaction, and I now beg to give my views as to the reason of their failure.

1. They were always built too small and too weak. The longest of previous submarine boats was 45 feet, or about half as long as my boats. Their small dimensions and weak plates made them useless in bad weather and dangerous for submersion, especially if touching the bottom, or if coming in contact with any vessel. The small air space available in such small boats also forced the crew to use chemical means to obtain pure air.

2. They have never been made for firing a fish torpedo, consequently they have had to endeavour to fix a mine to the bottom of a vessel, which I consider impracticable, considering the risk of contact with the vessel, which, especially if pitching or moving, might easily destroy the boat. This also necessitates a complication of clockwork

or electrical connections to enable the boat to get away to avoid the fatal risk of being destroyed by the attacked vessel, as was the case with the boat which sank the "Housatonic."

3. In all the early boats the mines were charged with only black powder, the effect of which was less destructive than that of the gun-cotton or dynamite in the fish torpedoes; and the effect of the explosion against a wooden ship was nothing like as serious as against the thin bottom plates of an ironclad.

4. All the boats hitherto in use have been propelled by hand power. This gave too much hard work to the crew, who could not take the boat any distance on the surface previous to the actual attack, and made it quite impossible to face any rough weather.

In my boats, the use of steam diminishes the number of men, and they have so little to do when below the surface, that the temperature, which is anyhow lower than in modern stokeholes, is no detriment; the stokers, for instance, in my boats, have nothing at all to do when the boats are submerged. My boats can go 150 miles and upwards, previous to the attack, without re-coaling.

5. All previous boats had most unreliable means of descending and ascending. The descent by steering downwards in the American boats, twenty years ago, was quite as dangerous as the attempts before and after that time to lower and raise the boats, and to keep them steady at any desired depth, by means of increasing and decreasing the weight of the boats by more or less water-ballast, or by altering their displacement.

None of these boats used the principle which I have applied to pull the boat down by mechanical means, while relying upon its always retained buoyancy for rising; so that if the mechanical apparatus fail, the boat rises at once to the surface. Nor did they have the tendency to steadiness given by the two forces of constant pulling down, by my horizontal screws, acting all the time, whether still or moving, against the pulling upwards caused by the buoyancy.

I should consider it most dangerous to rely upon a detachable weight in case of emergency, as the apparatus for detaching it would be always liable to fail.

I cannot imagine how the longitudinal instability of a submerged boat can possibly have been satisfactorily controlled by any of the means applied to the previous boats; and even if the appliances used had been more perfect, they would probably not have been sufficiently effective for such very light boats without much inertia. Even Gouvet's system of moving water or weights fore and aft inside the boat must act much more slowly, and cause more diving and oscillation than my rudders, which always remain in the horizontal, and thus control the slightest tendency of the boat to get out of the longitudinally horizontal position.

I consider it absolutely essential to keep the boat horizontal when moving, as any inclination downwards, with the impetus of a heavy boat, would almost to a certainty carry the boat below its safe depth before it could be effectually counteracted by shifting weights.

These are, as far as I have been able to ascertain, the more

important steps in the direction of submarine boats, which had been taken previous to my attention being drawn to the subject, five years ago.

The position, then, as regards torpedo warfare, seemed to me to be as follows:

The submarine mines, placed at the bottom or floating anchored, had been adopted generally; but they were acknowledged not to fully satisfy the requirements for port defence, because they were immovable, and were exposed to be picked up by the enemy.

The towed torpedoes of the Harvey class had not given satisfaction, and the spar torpedoes could only be used under very exceptional circumstances. The Whitehead and Schwarzkopf fish torpedoes were then the only ones which gave any hope of usefulness by future development.

Apart from the faults and difficulties in the construction and management of the fish torpedo itself, there seemed to be an almost insuperable difficulty in carrying it, with any degree of certainty, up to the short distance at which it could be considered infallibly effective.

The fish torpedo is practically a projectile, and the torpedo boat may be called the gun which fires it; but the great expense in time of peace, added to the certainty of losing a number of these boats in war, made this means of discharging torpedoes exceedingly costly and unreliable.

It seemed to me, therefore, of great importance to construct a means of carrying, with greater safety, the fish torpedoes up to such a short distance from the vessel to be attacked, as that the torpedo could not fail to hit.

The surface torpedo-boats at that date were met by machine-guns which made their attack in daytime almost impossible; and the improvements in the direction of greater speed and thicker protection of their vital parts, have been met by greater power and longer range of the quick-firing machine-guns, while their larger dimensions offer a target more easily hit. Thus, to-day, the surface torpedo-boats really do not offer much greater certainty of reaching striking distance than they did five years ago.

It seemed to me that a much greater chance would be given for carrying the Whitehead torpedo within striking distance, if, instead of trying to rush the distance by many boats all the time exposed to the destructive fire from machine-guns, I could carry the torpedo secretly up to this distance without the probability of being seen at all, and without any probability of being struck by the enemy's shot, even if seen.

This led me to take up—with a view to make it a practical success—the question of submarine boats; and, instead of publishing any accounts of my proposals, I thought it best to build at once such a submarine boat as could not be suspected of being only an experimental boat, but one really useful in war.

I propose to describe the boat itself, and then to give my views about its utility and manœuvring.

The first boat I built at Stockholm, and which I had the honour to run at the experiments in Sweden last September, in the presence of delegates from most of the leading Governments, is shown on the drawing No. 1. The following are its principal dimensions and details:

Length 64 feet, beam 9 feet, but over sponsons 12 feet, draft 11 feet; displacement 60 tons; speed, on measured mile, 9 knots; distance travelled without re-coaling, 150 miles; depth to which it can safely descend, about 50 feet.

Engines, surface condensing compound type, with 2 cylinders and cranks at 90°, and, at pressure of 100 lbs. to square inch, will indicate 100 horse-power. Boiler of ordinary marine return tube type, having 1 furnace, and about 200 square feet of heating surface.

Two hot water cisterns, rhomboidal in body, with spherical ends.

The boilers and cisterns contain about 8 tons of water. Both boilers and cisterns are made for a working pressure of 150 lbs. to square inch.

One fish torpedo, 14 feet, is carried outside on the bow, and discharged mechanically.

The sinking apparatus consists of 2 horizontal propellers driven by a 6 horse-power double cylinder engine. These propellers are placed in sponsons on each side of the boat.

One cold water tank in centre of boat, holding about 4 tons of water for regulating buoyancy. This tank is used as coal bunker when doing long surface runs. Crew, three men.

For longer distances, out of sight of the enemy, the boat runs on the surface, with the cupola and about 3 feet of its turtle back out of water, but by forced draught, blowing out its smoke under the surface.

When the boat arrives within such distance of the enemy that it might be discovered, it descends into the water so far that the cupola alone appears above water; this is done by taking in water into the cold water tanks sufficient to reduce the floatability to what my horizontal screws are capable of overpowering; she runs thus "awash" until she arrives so near that even the small cupola might be discovered, then she descends altogether below the surface and advances up to striking distance entirely submerged, unless she requires to show the cupola above the surface once or twice for a few seconds to adjust her direction.

The above-named reduced floatability is never done away with, but the descent from the "awash" position is effected by starting the horizontal screws, thus overcoming mechanically the buoyancy of the boat, which is pulled down to a less or greater depth, depending upon the speed given to the horizontal screws.

As the density of water does not alter at varying depths, I can always count upon the exact amount of buoyancy being available for raising the boat to the surface whenever I stop the horizontal screws, or for lifting the boat nearer to the surface when I reduce the speed of the engines driving them. Thus, if any failure of these engines or propellers were to take place the boat would at once rise to the surface.

NORDENFELT SUBMARINE BOAT.

No. 1. 64 FT. BOAT

No. 2. 100 FT. BOAT.

In addition to my controlling the depth by varying the speed of the horizontal propellers, I have applied an apparatus for definitely regulating the depth at which I mean to move; this consists of a valve which controls the steam supply to the small engine; this valve being held open by a weight adjustable on a lever, the piston of the valve is also in direct communication with the sea, in such a manner that when I reach a depth at which the pressure in the sea is more than the pressure of the weight, the valve closes, the engines stop, and the buoyancy raises the boat until the outside pressure diminishes, when the weight again opens the valve. By this means I exactly regulate the depth at which I desire to move.

When descending below the surface I carry altogether about eight tons of water, subject to the full pressure of steam, so that in case of more leakage than I can pump out of the boat by my steam pumps, I can at once counteract such leakage and rise to the surface by blowing out water. This must be much more reliable than to detach weights.

On the surface I drive the boat by working the boiler in the usual manner, and I keep up the temperature of the water in the cisterns to a degree corresponding to a steam pressure of 150 lbs. When I wish to descend, I close the ashpit and fire-door, then I close up the funnel inside boat and start the horizontal propellers.

At this moment I thus have, as propelling power under water, the steam which will be given off by the heated water (about eight tons), and this has been found sufficient for a distance run of 14 knots; or more than is required for an attack in war. On that occasion we had still over 20 lbs. pressure in the boiler when the boat was opened up.

The boat is laterally very stiff, as I carry some six tons of lead in the bilge.

Longitudinally the boat is balanced before starting by the arrangements of weights, and this can be adjusted by having more or less water in the two cisterns fore and aft.

When descending, the boat is perfectly horizontal, and is invariably kept so when moving under water, by means of the bow rudders operated by a plumb weight. These bow rudders have been found to act so perfectly, that there is actually no appreciable change from the horizontal position.

Although the centre of gravity is well under the metacentre, the boat is so sensitive longitudinally, that the bow rudders correct instantly any tendency to deviation from the horizontal position.

Since the Swedish trials in September last, I have had time to adapt to that boat all the more important improvements which have been suggested by the experience gained, so that this boat is now a thoroughly efficient instrument for practical use.

Three men are sufficient crew for the boat, and I have proved that these men do not require any other air for sustenance in comfort than what the air space in the boat itself contains.

The dimensions of this first boat, as well as its speed and proportions, were settled especially for defence of coasts where there is an archipelago, as in Sweden, the west of Scotland, &c., and for the defence of ports with long estuaries, for instance, London, Liver-

pool, &c., and I am still convinced that where handiness and small draught of water are important factors, these proportions cannot be much improved upon.

For the defence of open coasts and for operations where it may be necessary to keep the sea for days together, without being able to seek the shelter of inlets or the mouths of rivers, other and larger proportions will, of course, be desirable, and I am now constructing boats on such larger lines, feeling certain that both the smaller and larger types will become necessary.

The lines of my boats are drawn specially suitable for giving least resistance when the boats are submerged, consequently they are not so good when part of the boat is above water. The surface speed of my small boat being 9 knots, she is capable of even greater speed when submerged, thus she can always, whether on the surface or below, do 4 to 5 knots against a 4-mile current.

The question of what speed below water is most desirable, must be found out by experience, and must depend upon the room and depth of water available, and upon how far greater speed, when submerged, may tend to detract from the secrecy of attack, and upon other questions which can only be determined by lengthened practice by intelligent Officers, when fully trained to its use.

The following are the details of my larger boats (Drawing No. 2):—

Length 100 feet, beam 12 feet, displacement 160 tons, speed on measured mile 12 knots, distance travelled without re-coaling 900 miles, depth to which it can safely descend about 50 feet.

Engines are of surface condensing compound type, with two cylinders, and cranks at 90°, and at a pressure of 100 lbs. of steam will indicate 250 horse-power.

Boiler is of the ordinary marine return tube type, having two furnaces; about 750 square feet of heating surface.

Hot water cistern is rhomboidal in body with spherical ends.

Both boiler and cistern are made for a working pressure of 150 lbs. per square inch.

Two fish torpedoes, 14 feet long, are carried outside on the bow, which are discharged mechanically.

Sinking apparatus consists of two vertical propellers driven by two engines, which each indicate 6 horse-power.

Two main cold water cisterns placed at each end, and containing 15 tons of water each, also one in centre of boat for regulating buoyancy, containing 7 tons, coal bunkers on the side of boiler; 8 tons of coal are carried at the side of hot water cistern and in middle of boat.

Crew.—Three men in a watch; two watches carried.

With coal in the bunkers only, this boat can keep the sea for five days or more, and thus would be especially suitable for cruising off the south coast of England, ready to defend any port in the channel which might be threatened, or for action as despatch boat in passing unseen an enemy's line of vessels.

Both the large and small boats are, of course, provided with compasses, pressure gauges, and all instruments required for gauging the

depth under the surface, the balancing of the boat, the purity of the air, and for all other purposes connected with submarine warfare.

The three main points in my system of submarine boat to which I particularly wish to draw attention, are :—

1st. That by using water as the means of storing up energy, I am in possession of a reservoir which can never get out of order and which can be replaced at any hour in any part of the world, and without any extraneous assistance from shore or other ships. Whereas if electricity were used, delicate and special apparatus would have to be employed as reservoirs of energy, such as accumulators or batteries, which if they should require repair or replacement would render the boat completely *hors de combat*, unless she were within reach of some electrical depôt. Also the durability of the cistern containing the water is immensely greater than of electrical apparatuses, which—should a run of any distance be required—would still have to be provided with engines for the replenishing of their power.

These objections also lie against the use of caustic soda or compressed air.

Besides, after carefully investigating what could be done in other ways, I was fully convinced that I could by no other method store so much energy as by using heated water, especially as I have made it a point to design engines for my boats in such a manner that as long as I can have high pressure in my boiler I can use expansion; yet as the pressure falls in the boiler by reason of the steam being used when under water, I can regulate my engines so that they will work well down to and even below the atmospheric pressure.

The reason of all others which at once decided me to adopt the hot-water system, was the enormous factor of safety obtained by my being able to blow out by steam pressure, without the use of machinery, large weights of water, which would lighten the boat and counteract any leak likely to occur.

Finally, I preferred to use the hot-water system because, the motive power being steam, ordinary marine engineers are at once familiar with it, and would have more confidence in the boat than if any new, delicate, or comparatively untried system were adopted.

2nd. The submerging the boat by mechanical means. I feel confident that previous attempts have proved unsuccessful mainly because either they depended upon varying the displacement of the boat by taking in water to submerge her, and to regulate the depth at which they desired to operate, or they descended by steering downwards.

My objection to the first-named method of descending by taking in water, and thus increasing the specific gravity of the boat, is, that practically there is no difference of the specific gravity of water on the surface and at 50 feet depth; thus, when the boat has lost its buoyancy at the surface, it has also no buoyancy at any given depth, and the risk is thus very great of suddenly descending beyond a safe depth.

Further, by this method they relied upon some mechanical means for ascending by ejecting water. In case such mechanical means failed, the boat would be lost.

As regards the method of descending by steering downwards, I need only point out the great risk of allowing an object 100 feet long and of great weight to proceed in the downward direction even at a small angle, as the impetus gained would very easily carry it beyond safe depth so quickly that they might not have time to check it.

On the other hand, by my system I rely upon no mechanical means for rising. I keep myself, by means of the speed of the horizontal propellers and the regulators, at any desired depth, with a sufficient force to keep steady when advancing at that depth; and as I never cause the boat to leave the horizontal position, I am safe against the effect of impetus in a downward direction.

3rd. The horizontal position I have found to be a *sine qua non* for a submarine boat, and I have already above shown the great risk in allowing the boat to descend at an inclination. I have, therefore, provided rudders which I prefer to place in the bow of the boat, and which by the action of a plumb weight are always held in the horizontal position, and, therefore, should the boat from any cause tend to take a direction other than the horizontal, these rudders will immediately bring the boat back to the horizontal position.

During experiments continued for a couple of years I have found these rudders perfectly reliable, and they have never failed to effect their purpose.

In addition to these three main features of my submarine boats there are a few more points to which I wish to direct attention.

There is really no trouble at all about the heat or the sufficiency of sound fresh air in the boats.

The heat after the 14 miles run above named was only 32° C. (90° F.), and after the first run at Landskrona, when the crew had been closed in from the outer air for three hours, the temperature was taken by two of the delegated Officers at 31° C. (88° F.), while I am informed that in some monitors the stokehole temperature rises to 49° C. (120° F.), and I suppose that it is not much cooler in some of the larger modern ironclads.

As to the purity of air, there have been four men enclosed in the boat for six hours without any appreciable diminution in the length of flame of a tallow candle placed on the floor, the level where the air should be most impure.

There is, of course, no reason why I should not carry compressed air, caustic potash, chlorine, or other well-known chemical compounds for purifying the air, in lieu of the lead ballast, except that I do not consider the complication to be necessary; as, in the case of war, many opportunities would occur for opening up the cupola for a minute, or for turning on the forced draught, and filling the boat again with pure air.

I have not had the slightest difficulty in finding crews. My first engineer was one from the merchant service, my second one was engineer in the Swedish Navy, and my third one was again a civilian; any number of stokers have always offered their services, and many Swedish Naval Officers have urged me to let them command the boat. The risk to the crews ought to be very slight, and in war I consider

that they would be safer in my boats than in many other positions. In case of accident the boat can always come to the surface and the men can escape with life-belts.

The Captain would soon be accustomed to study and become familiar with the appearance of the coast and other objects from the low level of the cupola when awash. Still, this, like all other parts of the boat, has to be studied, and men have to be trained in order to make the boat really efficient. No untrained man can hit a bullseye, or ride a bicycle, or play the piano; still they are easy things enough when learnt.

I have delayed the completion of my first boat for years in order to take away all complications. I have nothing but ordinary steam and ordinary engines; still, the engineer and the stoker should be so familiar with the position of all cocks, valves, and pumps as to find instantly and almost mechanically the right handle at any important moment.

The Officers who are to command these boats ought to study, perhaps for years, their manœuvring power, and the best manner in which they are to be made most useful in war. If not, they may fail at any moment when they are relied upon by the naval authorities. I put very great strain upon this training in good time, as I am bound to admit that any number of these boats, if constructed suddenly before the commencement of a great war, would probably not be as useful as half their number in the hands of Officers and crews who had previously become familiar with them for years in time of peace.

In training crews they would, of course, at first work for a time with the boat "awash," showing only the cupola, as, even in time of war, the boat will often be most useful also in this position.

My compasses work in the same manner as in all other iron ships; that is, they do not work as satisfactorily as when raised far above the iron—but, as they work exactly the same whether the boat is on the surface or submerged, I can always take the bearing before descending and then be safely guided by the compass below.

General Hardinge Steward has suggested to apply a telescopic mirror, and this may be very useful on occasions when the boat may not like to show its entire cupola, nor to descend altogether, but wishes to advance while keeping the enemy's ship in view with only the small tube which holds the mirror above water.

Lieutenant Hovgaard suggests that some electrical power should be carried in accumulators in addition to the steam power; this can of course be done if found useful, but I would prefer to avoid complication by carrying the weight of such accumulators and electrical motor in additional heated water.

The main safety of the boat, of course, lies in the utter improbability of the enemy knowing that the boat is near, or that any attack is intended; next, it lies in the very short period of a few seconds in which the cupola appears above water, and which would generally not be long enough to enable the enemy's guns to ascertain the range. If the cupola be hit the boat is not disabled, as there is a cover which can at once be slung across the opening and make it watertight, so that

the boat can again descend out of sight and go away to put on a spare cupola.

The actual turtle back of the boat can easily be protected against the shots of machine-guns or quick-firing guns by its being covered by a 1-inch steel plate in addition to the skin, but any shells, if they hit the turtle back, would strike at such an exceedingly acute angle that this additional weight would really not be required.

When the boat runs "awash" the water which covers the remainder of the entire boat, except the cupola, would be the safest armour that could possibly be devised.

My boats are armed with one or two Whitehead torpedoes in tubes, and as soon as my controlled electrical torpedo is ready, I propose to tow one of these as well.

This torpedo will offer the advantage that steel wire nets would be no protection against it, as the nets would be torn asunder or brought close to the ship's side by the impetus of the torpedo weighing 4 tons, striking with a speed of fifteen miles an hour, so that its charge of 300 lbs. of dynamite must explode as near to the ship as is required to make that heavy charge thoroughly effective.

To defend the submarine boat against surface torpedo boats, I mean to carry either a 2-lb. quick-firing shell-gun or a couple of MacVoy's small spring torpedoes, besides which my boats are so strong and so handy, that they would ram and sink any surface torpedo boat with which they may come into contact.

As a large ironclad costs as much as from 50 to 100 of my submarine boats, the question of expense cannot be of much consideration, and I am convinced that as soon as different nations become familiar with the boats, and when naval Officers, by their practical use, have determined the best way of making their manœuvring most effective, they must be adopted in large numbers. As soon as it is acknowledged that the boats are safe, and can be easily managed, in consequence of my having made them simple and easily handled, by eliminating all complicated or dangerous motive powers or mechanisms, and by only calling upon the boats to do what they can easily do, without any reminiscences of the fantastic though fascinating writings of Jules Verne, it does not require much imagination on my part to see, a few years hence, great numbers of these boats defending such waters as the Thames, the Mersey, the Clyde, the Humber, the Straits of Gibraltar, the Bosphorus and Dardanelles, the Suez Canal, Rio Janeiro, the La Plata, and such ports as Portsmouth, Plymouth, Cork, Edinburgh, Hamburg, Wilhelmshafen, Copenhagen, Kiel, Carlskrona, Cronstadt, Brest, Cherbourg, Ferrol, Lisbon, Cadiz, Carthage, Marseilles, Toulon, Genoa, Spezia, Naples, Trieste, Odessa, Alexandria, New York, New Orleans, and all the important stations and shipping ports in India, China, Japan, Australia, South Africa, and the American continents.

In almost every case, when I examine the charts of such ports, I find some especially suitable points in favour of the use of submarine boats.

I have heard the opinion expressed that the general adoption of

submarine boats may act detrimentally to the interests of this country, because the boats might enable smaller countries to defend their ports to a certain degree against more powerful navies.

It is true that the submarine boats are important in the first instance to countries which cannot afford to follow the constantly changing systems of costly ironclads—but, rich though England be, it must be important also to this great Empire, if a cheap means of defence can be worked out for her coasts, her Colonies, and her coaling stations, which would leave her ironclads free to fight on the high seas, and her swift cruisers free to follow and protect her own merchant navy, or to destroy the merchant navies and commerce of her enemies.

I have never heard it stated that the British Navy has too many modern war-ships even for these purposes, let alone coast defence, and I cannot imagine any less costly means of defence of Colonial ports and coaling stations than such submarine boats as, in the absence of fortifications, may be able to defend their commerce until there is time for the Imperial Navy to come to their assistance.

Admiral ARTHUR, O.B.: Mr. Chairman, your Royal Highness, and gentlemen, this is a subject in which I have taken very great interest. I do not intend to address you at any length, but there are a few points on which I think we may dwell with great satisfaction. I consider that not the least important feature of the interesting paper read by Mr. Nordenfelt to-day is the clear way in which he has pointed out to us the absolute necessity, in all vessels which navigate under water, of keeping the horizontal position. This has been the point which has led us astray with the Whitehead. If we had maintained from the first the horizontal position by means of two horizontal rudders, one at each extremity, instead of one rudder placed in the stern only, we should now be in a much better position than we are. The Whitehead torpedo is a submarine boat, and has been going now upwards of fifteen years. We have constantly strengthened it to correct the danger increased by its going at too great a depth, and we have only lately come to the conclusion which Mr. Nordenfelt has so clearly put before us—the absolute necessity of maintaining a horizontal position to prevent an abnormal dive. I have reported on a great number of submarine boats of many descriptions, but the report has always concluded by saying that I could conceive of no opportunity for using these boats with any effect whilst under water. I was one day discussing this subject with a Russian naval Officer who had commanded a submarine vessel for three years, and I asked him that question: "Can you conceive of any situation in naval warfare in which a submarine vessel could be of any use?" His answer was to the point, and conclusive; he said, "No, certainly not; whilst a submarine vessel is submerged she is totally useless. But let the submarine vessel be so constructed that she can stick with her turtle-back just appearing above water, and then I will approach the whole British fleet, and allow them to fire on me, and I undertake to get into position near enough to discharge the Whitehead torpedo." I think that is the point we must come to. We want torpedo-boats that can steam at a high speed with almost total immersion. Undoubtedly to do this they must have the power of going entirely under water, but such would be exceptional and for very short periods. My opinion is that all torpedo-boats should be submarine boats—that is to say, they must have the power of going under water if required, but they must be able to steam at a high rate of speed along the surface. I should think we may eventually arrive at being able to solve the question of maintaining the same speed they have at present, viz., of 20 knots an hour; we should get that at a light draught, for which purpose some alteration in the position of the screws would be necessary, then with the turtle-back awash we should get 13 knots—and we may be quite satisfied with 6 knots or less on total immersion. I think those

are the two principal points that we have to dwell on to-day. You will all agree with me that the system of drawing a vessel down instead of guiding her down is the one we must rely upon. That is one of the most novel points in Mr. Nordenfelt's design, and I think it is the most important one.

Admiral the Right Hon. Sir ASTLEY COOPER KEY, G.C.B., F.R.S.: In any remarks that we may make on this very interesting paper that we have heard read by Mr. Nordenfelt on a somewhat startling subject, I at all events will speak with very great diffidence on the points raised, as I have never seen anything in the shape of a submarine locomotive at work. Mr. Nordenfelt has had actual experience in the management of one of them for some years, and he speaks, therefore, not only from the sources of his great knowledge and engineering skill, but with the great power of practical experience. I may mention that Mr. Nordenfelt has in his historical summary omitted to include an invention of a submarine boat which was considered to have been of considerable importance during the Crimean war; it was proposed by Mr. Scott Russell, one of the most eminent engineers of the day. It was thought highly of by the Government, and Lord Palmerston, then Prime Minister, sanctioned an expenditure of 7,000*l.* on its construction and trial. Sir James Hope, Sir James Sulivan, and I were appointed to report on its capabilities. I need scarcely say that it was a failure, but it serves to illustrate the great advance that Mr. Nordenfelt has made in the submarine boat he now proposes. I did not like the look of Mr. Scott Russell's vessel. It was merely a large diving-bell, like an inverted boat. Ten men were supposed to go in it. It was to be lowered by admitting water into a compartment, and to be raised by pumping it out or by blowing it out with compressed air. It went down to the bottom with the men under it; they were to walk on the bottom and propel the boat by pressing against thwarts fixed to the under side of the boat. The boat looked rather doubtful as to its rising to the surface, having a long strop and thimble attached, and a buoy with long buoy-rope. The boat went down and remained there twenty minutes; a tackle was sent down hooked to the strop, and up came the boat just in time. They were bold enough to try it a second time, but with no greater success. The second time it came up suddenly, blew like a whale, and capsized. I mention this to show that many years ago the submarine boat was considered an important weapon of offence; in that case it had a special object. As I have said, in any remarks I may make on this proposal I do it with great diffidence, but I do not think Mr. Nordenfelt has paid sufficient attention to the necessity for speed. He says that when floating on the water she will go 9 knots, and therefore when she is totally immersed she will go faster. I should like to see this proved—until then I question it—and I think it is of importance. The armament of this boat is one Whitehead torpedo. If she is to attack by creeping up to a vessel (which I think is by far the surer plan) it must be to a vessel at rest. If a vessel is at rest she will probably have her nets out, against which a Whitehead torpedo of the old type has very little effect, and thus you have a most formidable vessel only armed with one Whitehead, against which a ship at anchor is quite protected. If, however, the ship is under way and has greater speed she can of course escape from her assailant.

Mr. NORDENFELT: The larger boat runs 12 or 13.

Sir COOPER KEY: I should be very pleased to see the larger boat. There are one or two questions I should like to ask. I think it is a matter of very great importance, as Mr. Nordenfelt has pointed out, that the smoke is discharged under water; but I should like to know, when it is so discharged, does it make its appearance at the surface?

Mr. NORDENFELT: It bubbles a little, but no smoke comes out.

Sir COOPER KEY: I should be rather afraid that it might appear on the surface, and thus indicate the approach of the vessel.

Mr. NORDENFELT: Not when it is under the water.

Sir COOPER KEY: You say she can be sunk to a safety depth: does that safety depth mean that beyond it the body of the boat will be crushed or altered in shape?

Mr. NORDENFELT: It means that the buoyancy would be taken away.

Sir COOPER KEY: Those are two points I wished to know. As regards the compass, which it is suggested might be a difficulty, I do not believe you will find

it so, because Sir William Thomson's compass when used on an ironclad surrounded by iron in a conning-tower works satisfactorily.

Mr. NORDENFELT: I was told the same thing yesterday: I was not previously aware of it.

Sir COOPER KEY: I do not think there will be a difficulty on that point. The most important point connected with submarine boats is that which has been pointed out by Admiral Arthur. In our investigations on the boat I have referred to during the Crimean war, we came to the conclusion that it would be perfectly useless, because you cannot see under water sufficiently to guide you to any given object. In Mr. Nordenfelt's boat there is no means of seeing under water; therefore I believe that unless you can approach a vessel with your cupola above water, to see where your enemy is, and the direction and distance you should steer, you will not effect much. You might approach it this way during twilight, or by night, or in a fog without much difficulty. I doubt whether anyone would go down under water and fire the only implement of destruction he possesses at a vessel that he does not see; but I do think that with the cupola above water, or with the smaller cupola and projecting mirror, it would prove a very formidable means of attack. I think the principles which Mr. Nordenfelt has adopted—in the first place having his stored energy in such a simple medium as hot water, and in the second place having the means of raising and lowering the boat by the mechanical means of vertical screws and bow rudders—are both sound and admirable. We have heard much nonsense talked about regulating the depth by the specific gravity of the boat when under water. If, however, she is made heavier than the water, down she goes to the bottom. If she is lighter than the water, she comes to the top. Without mechanical appliances there is no reliable means of keeping her at a fixed distance below the surface or having it in your power to raise and lower the boat with regularity. I believe that this submarine boat has a great future, and that Mr. Nordenfelt has achieved a great success. As I have said, the question of speed is one to which a little more attention might be paid; and it must also be borne in mind that when you are going to fire a torpedo you must see the vessel you are going to fire at.

Vice-Admiral H.R.H. DUKE OF EDINBURGH, K.G.: Sir Andrew Clarke and gentlemen, I am very glad to have been able to be present to hear this lecture of my friend Mr. Nordenfelt, who has already done so much for science and for the improvement of many matters connected with warfare. I may say that I fully agree with Sir Cooper Key, who has just said that Mr. Nordenfelt has done very much towards solving a problem which is likely to be of great importance in future naval operations. He has had the great advantage of practical experience with these boats, and they have so far proved a great success over all preceding attempts to manufacture a submarine boat. There is one point which I think Mr. Nordenfelt's experience has not tested, or in which he has not already gained experience—and it is one which might be raised in a discussion like the present. We have not heard in the lecture—nor has it been in any other way mentioned—in what manner the torpedo is to be delivered against the ship. It has already been said that when you are attacking a ship absolutely at rest, which means a ship at anchor, having risen to the surface and taken your exact bearings, you may with a tolerable degree of certainty be able to strike the vessel, provided the power of the torpedo is sufficient to force in the nets and burst near enough to the ship. But not having heard it stated in what manner the torpedo is to be discharged, it strikes me that the submarine boat may get so near to a ship that when the explosion of so large a charge as 300 lbs. of dynamite takes place, the people in the boat or the boat itself may be destroyed by it. I say this, because in the Service we never should dream of exploding a large charge of dynamite if we had divers down within a very great distance, and those who have seen submarine mines exploded will know at what an enormous distance fish are destroyed by them. That is owing to the simple fact—which has been more or less described by Mr. Nordenfelt himself—that water is of the same density at all distances; in other words, it is an incompressible substance, and a blow struck at a certain place is transmitted a very great distance before its effects are in any way diminished. I feel, therefore, that it is extremely desirable that experiments should be made before risking the lives of men in a boat of this descrip-

tion for the purpose of seeing whether they would suffer in the way I have alluded to. When turret-ships were first constructed, an experiment was carried out, if I mistake not, at Spithead, on board the "Royal Sovereign," where they put goats, cocks and hens inside one of the turrets, and fired the gun to see the effect that the explosion would be likely to have upon the gun's crew. An experiment of a similar nature might be tried with the submarine boat. I do not mean that goats or cocks and hens should be put under water for any length of time, but remembering the example I have given of fish being destroyed at such an immense distance, you might have vessels containing fish placed at certain distances, and in that way ascertain the destructive limits of the explosion. I merely throw this out as a suggestion, but I think the point is worthy of consideration. I will only add how very much I have enjoyed listening to this lecture, and how heartily I wish success to the invention which Mr. Nordenfelt has brought before us.

Admiral FREMANTLE: I rise simply to ask a question on a point which I think Mr. Nordenfelt did not explain to us, and which has not been touched upon by other speakers. I wish to know the method of discharge which is to be adopted for this torpedo below water, and also whether it would have any effect on the horizontality of the boat when it is discharged, because, as Mr. Nordenfelt has told us, it is a very great advantage to keep the boat in a horizontal position.

Admiral SELWYN: Mr. Chairman, your Royal Highness, and gentlemen, I admire, in common with most of the gentlemen present, the extreme ingenuity that Mr. Nordenfelt has displayed in this comparatively new subject, because he has been the first to consider the whole of the forces in operation, which a great many of us have left unattended to. I am afraid, I must confess, that in some parts of it, I myself, in designing some years ago a submarine boat for the Turkish Government, also relied upon man power, but I did so because I never intended that it should be used for anything but cutting off submarine mines. In that boat we proposed to use sulphate of soda for the absorption of the carbonic acid, which I believe is by far the best—Glauber's salts—and I have no doubt that would meet all the requirements in a very small boat. Mr. Nordenfelt has now taken us into the consideration of how big we may make these vessels. He has begun with a very practical and useful illustration, but he has forced us to consider that there is scarcely any limit to the size to which we may usefully take this vessel. It at once supersedes in a very large degree the necessity for armour or for considerations of that kind, and eventually we may have to acknowledge that Jules Verne was not very far wrong when he led us in a submarine vessel all round the ocean. The question of propulsion at a high speed is one which has recently approached solution more nearly than we have ever known it before. At the Inventions Exhibition a steam-engine was shown for the first time which combined enormous speed with great economy. Our rotary engines in the past have given us great speed, or up to what we called great speed—that is, up to about 1,000 or 2,000 revolutions a minute. This engine, the invention of Mr. Parsons, the son of the late Lord Rosse, for the first time gives us high economy—21 expansions, which is very high economy indeed in an engine which is capable of 16,000 revolutions a minute. Now this is a question of propulsion which is very easily understood when we consider that one immense difficulty has been to obtain reciprocating engines which would drive at high speeds, and drive a small screw of this kind at high speeds such as we desire, without too much liability to breaking down. This, which belongs to a certain extent to the class of rotary engines—but is more a turbine engine than a rotary engine—is free from all those objections. It is visible now at Lincoln's-Inn, where it lights the whole of the establishment and gives double the number of electric lights for the same boiler power that any other engine does. This is an enormous improvement, and I could not suggest to anyone a better means of measuring the actual effect produced than that of the increase in the number of electric lamps. While our indicator diagrams are liable to a great many errors, the number of electric lights you can burn from a given power is liable to no such error—it is an absolute measure of efficiency. With such an engine there seems to me no great difficulty in driving a vessel of this kind at any speed that any torpedo-boat has ever yet attained. I should be disposed to say that a very little further consideration would lead to the banishment of the screw altogether, and to a speed very much

exceeding that which has already been obtained by torpedo-boats. That torpedo-boats would also rise in speed considerably is of course to be expected, but that would at once meet the objection to the low speed already attained. With simple means such as Mr. Nordenfelt has used, I do not see that we can find fault with the speed of 9 and 13 knots. I think we ought to congratulate him that he has done so well. I also see no reason, derived from the increased frictional surfaces, why the speed obtained under water should not be greater than that obtained above it, for the bow wave, which has long been known as an enemy of high speeds, which prevents a torpedo-boat obtaining any great speed till she begins to ride upon it, is clearly absent when you drive a vessel of this shape entirely under water. The fish is endowed with a perfectly devised shape for the work it has to do under water, and when we imitate a fish above water I think we very often commit a grave error. When Mr. Nordenfelt devises a submarine boat, he naturally adopts the submarine form, and I think very wisely does so. With regard to the procedure above water within the distances at which I presume Mr. Nordenfelt would use the torpedo, I really do not see that there is any great difficulty in setting a course—considering the current and other circumstances—very nearly as well as he could above water. I believe the faculty of rising is most important, and that it has been accomplished in the most perfect manner by Mr. Nordenfelt's device of the vertical screw; but that there is any grave difficulty other than that which must necessarily accompany fogs and darkness in successful attack by a torpedo, I really do not see. I think Mr. Nordenfelt is to be congratulated on having made an enormous step forward, and one which I am sure has a great future before it.

Admiral BOYS: There are two questions that I should like to ask, but I will premise by expressing my thanks to Mr. Nordenfelt for introducing this subject, and complimenting him on his invention. It is not like very many inventions that are brought before us, and which simply exist upon paper; but here is an implement that really exists that Mr. Nordenfelt has to a certain extent perfected. He has built it and worked it. I am sure he is anxious for criticism, because by asking questions about designs, and pointing out what we may imagine to be their failings, inventors and gentlemen like Mr. Nordenfelt are able to make improvements and perfect them. One question I would ask is, what depth of water Mr. Nordenfelt thinks is necessary for the navigation of his larger vessel, because it appears to me that the immunity of a vessel from the attack of these boats will depend to a great extent upon the shallowness of the water she may be anchored in. I should also like to know how the torpedo is placed in the discharging tube which I see in the drawing; must it be placed there before the vessel is started? And then, how he proposes to discharge two torpedoes, because if there is only one tube—

Mr. NORDENFELT: There are two tubes.

Admiral BOYS: Is one below the other?

Mr. NORDENFELT: They are parallel to one another.

Admiral BOYS: I may also point out that this larger vessel gets to a considerable size, and the actual pointing of the torpedo depends upon the pointing of the vessel. The vessel is actually submerged until she gets within striking distance, then rises to discharge her torpedo, and that appears to me to be rather a difficult point.

Captain CURTIS, R.N.: I should like to supplement Admiral Boys' question by asking how far the submarine vessel must be from the ironclad for the torpedo to strike it, because if it is any distance off at the angle it is laid at, it seems as if it would be likely to go under the vessel. Also whether by its being so close to the vessel would the pressure of the water be likely to compress the submarine vessel. Then I should like to know whether in a rough sea the water does not come through the funnel.¹

Mr. NORDENFELT: There is no funnel.

Captain CURTIS: Does Mr. Nordenfelt contemplate the use of torpedo-nets of any depth in estuaries to counteract the effect of his torpedo-boat? I anticipate the time when ships will not carry their own nets and spars, but will be accompanied by covering ships laden with tubes that will fit into one another, fitted with

¹ I should have said, when not awash running above water in a rough sea, is the sea liable to enter the aperture where the draft is forced through?

jackstays and nets to them. Fleets will be eventually folded, as you would fold sheep, with openings for ingress and egress. If a ship is to carry all the torpedo-defence gear that I understand they have in present use, perhaps some younger Officer, who is more acquainted with the subject than I am, will tell us how long it will take to get a ship ready for action in case the fleet is suddenly attacked when off a port. For my own part I think it will take some considerable time under such circumstances to prepare for action.¹

Admiral GORE JONES: His Royal Highness has touched upon the fact of the torpedo-boat being very likely to get too close, and has suggested that something in the shape of nautical cocks and hens or fish were to be put up to test that. Now I can state from actual experience that that has been actually tested in America. Experiments have been tried in New York with crates and crusher-gauges and other appliances to find out how far the different explosives would act at different depths and distances, and on one occasion when these experiments were being tried a large school of porpoises was seen approaching. The Officer waited until the porpoises were within 200 yards of the 200 lbs. of dynamite, and then fired it, and in an instant the whole school of porpoises were up in the air, going round and round like flying fish. Three dropped dead on the water and the others were lying helpless and were secured for oil. This will show pretty clearly what the tremendous effect of a large explosive charge in water would be, and I mention it as a practical thing that has been tried. Not that I am at all afraid of a submarine boat getting too close to the enemy. If a small boat blows up a big ironclad I think she will have expended her life most happily. I am not at all afraid of it. But if they do get too close there is no doubt there is a great danger, as His Royal Highness has pointed out. With regard to the submarine boat, I really know nothing about it, and therefore shall not attempt to speak upon it.

Major-General HAUDINGE STEWARD, R.E.: I had the pleasure of seeing this experimental boat tried in Sweden in the autumn of last year, and, on the whole, I think almost all the Officers were very much impressed with it. We saw it on the last day of the trials, under the most unfavourable circumstances possible—that was in a dead calm. The water was as smooth as glass, and a Spanish Torpedo Officer who was on the yard-arm said he could see the torpedo-boat approaching at a distance of 500 metres. He made a great point of this, but the boat was running near the surface, and its general position was known, so I think you will all agree with me that the precise case may not occur again. The boat was a small boat, but I understand that Mr. Nordenfelt has designed a larger one. Since I saw the boat, torpedo tubes have been added to the bows, and I do not see any reason why they cannot be very well used. Some speakers have referred to the danger that may arise by the explosion of a charge of dynamite under water while the boat itself is under water, but I do not apprehend any danger at all. I have been assured by an Admiral now here, that on one occasion when a small charge of 60 lbs. of gun-cotton, such as would be used with the Whitehead torpedo, was fired at Portsmouth, a diver was accidentally below water and within 100 yards of the charge, and nothing happened even to the glass eyes of the helmet, though the diver felt the vibration of the water. The charge which destroyed the porpoises, and which Admiral Gore Jones has mentioned, was I expect a large ground mine fired by the land engineers. I was very pleased to hear what Admiral Arthur said about boats of the kind now under consideration being used principally for running *on the surface*, and I hope that that will be their future rôle. It is all very well to say that you can do a great deal of business with an ordinary torpedo-boat that runs 20 knots, or even with the second class boats, but unfortunately we have not got enough of these boats. If under fairly favourable circumstances you are going to attack vessels lying in the offing a few miles from the entrance of a port, you must expect a loss of 30 per cent. of the boats you use; that means that if you take five

---

¹ I am of opinion that merchant steamers should be laden with torpedo defence materials and accompany fleets; when they come to, off the enemy's port, working parties from each ship should be sent on board to get their portion of the defence material and fix it where required—"Nets break a heavy sea."

you may lose two, and if you take eight you may lose three, and even then you run the chance of being beaten off. But, as a member of the Council of the Naval and Volunteer Defence Association, I have to consider with others the defence of commercial harbours, and I have also to deal with the defence of Colonial ports. I am in a position to state that many of our ports do not possess even the proportion that is to go to the bottom. It comes to this, that if you want to economically defend a port, it is better to have a boat that does not show at all. Then, another thing one must remember, and that is that the moral effect of this boat would be enormous. I am perfectly certain that foreign war vessels would not lay off a port to intercept outward and homeward bound vessels if they knew that there was a submarine vessel inside that could come out without being seen. I certainly think that 10,000*l.* would be very well spent in providing a vessel of this class.

MR. ANDERSON, C.E.: I am afraid I cannot say anything of interest on this subject, except to state that it is well known, through the late Mr. Froude's investigations, that a fish-shaped vessel under water is in much more favourable circumstances for obtaining high speed than any vessel on the surface of the water, because it is established theoretically that a vessel of easy lines completely submarine meets with no resistance at all except the skin friction of the water, no resistance, I mean, such as that which arises from the bow wave, and therefore I believe that if Mr. Nordenfelt will apply a little more ingenuity and perseverance to the perfecting of his boat, the result will be the attainment of a very high speed under water, and consequently a most formidable vessel. It seems to me also that the precaution which Mr. Nordenfelt has taken against the danger of the vessel continuing to sink, as it would naturally tend to do in consequence of the contractions of volume due to the increased pressure arising from increasing depth, will be found to constitute the cardinal features in submarine boats.

MR. NORDENFELT (in reply): His Royal Highness has drawn attention to several very important points which I could not very well put into the lecture, and upon some of which I, not being a sailor, must speak with a considerable amount of diffidence. To begin with, as to the question of resistance—the difference of resistance when going below and when being on the surface—in a submarine boat the resistance differs so much from that in a surface boat that I should like to draw attention to it. In the first instance, in my boat the additional surface immersed when it is under water to that which is immersed when she is running awash is extremely small. In an ordinary surface boat the portion immersed is very small, but the portion above is comparatively immense, and if you go down another foot you increase the surface friction tremendously all along the boat. In my submarine boat you increase it very little, as it is only the small top of the turtle-back which is out of water when the boat is on the surface. As Mr. Anderson is good enough to say, I believe it is absolutely proved that with this sort of lines the speed below for a given consumption of fuel to a given boat must be greater than the speed above. The factor of safety of course is manifold. Safety as against general risks of seamanship, of being struck or striking the bottom, or anything of that kind, I have endeavoured to ensure by making the boat very strong and also by the fact that if my machinery fails I float up. As long as my regulator acts I cannot go below the point at which it is set, and then I have a very large proportion of water which I can blow out under high steam pressure by simply turning a couple of handles. I quite believe that by degrees we may find means for increasing the factor of safety, but I think for the present that is sufficient. Then as to the risk which a boat would run in discharging a torpedo against a ship. I am not aware that anybody has fired Whiteheads from a submarine boat. No doubt the boat which sank the “Housatonic” went down with her, because carrying nothing but a spar torpedo she had to run close up to the attacked ship, but now when you fire a Whitehead you can of course determine the distance which you consider safe, and I hope the English Government, or any other Government, will carry out systematic trials to determine that point, probably arriving at the conclusion that a Whitehead carrying from 30 to 60 lbs. of gun-cotton must not be fired at a shorter distance, say, than 50, or than 100 yards, and that a torpedo like my controlled torpedo, which will fire 300 or 400 lbs., must not be fired within 300 or 400 yards. My controlled torpedo can be steered, but the Whitehead is not steered, and they will have to

determine at what distance a Whitehead cannot miss the side of a ship; I should say at 200 to 300 yards. I therefore consider that a Whitehead can safely be discharged from my boat, but I speak of course under correction, depending upon trials to come. I hold that I can always stop the boat in time, because during the last 1,000 yards if I run from 3,000 to 1,000 awash, and at the last 1,000 yards if I run below I know my speed, my number of revolutions, and my time, and I ought to be able to calculate the distance so far to a certainty that I cannot come within 200 yards. I should know the time it takes a certain given number of revolutions to move the boat about 800 yards. If, however, there are very strong currents where I cannot control the boat, I can always at the last moment run up to the surface and fire from there. One Officer spoke about the effect of having a fixed angle for firing. The angle need not be fixed, because I can have a screw to raise one end if I want it, but generally 10° to 12° is the angle given to a torpedo, as I fire under water and at short range 4° to 5° will probably be found sufficient. We might be at a longer distance than I meant to fire it; in that case it would be safer to have the torpedo laid at a smaller angle. If I do not feel certain of my position I can always come up, see where I am, and if I am too near go down to retire, and if too far either fire where I am or go down and advance. The net, I believe, is supposed to hang 30 feet down. Of course an ordinary Whitehead could not be used when the ship lies still, supposing the net to be efficient. If a ship moves, or if a number of ships move together, I do not suppose they would have the nets, and if they moved in narrow waters they certainly would not carry nets, because of the difficulty of steering. I suppose a number of ships together would not move at much more than 7 or 8 knots, and in difficult water, at 7 or 8 knots, the nets down would very seriously interfere with the steering and cause risk of collisions. However, I do not want to be brought to-day into the net question. If a ship lies still with a net which keeps off the Whitehead, of course my Whitehead is kept off in the same way as a Whitehead fired from a surface boat; but if I fire one of my own controlled torpedoes, which weigh 4 or 5 tons, with a striking velocity of 15 miles per hour, the inertia must necessarily either tear the net to pieces or bring the net so close to the ship that the very heavy charge of dynamite will have its effect. As to the danger of the discharge of the torpedo doing harm to the submarine boat, the effect of the explosion is generally up and down, and its horizontal effect is very much smaller. I am speaking generally, as I have not before me the figures of any actual experiments. I am certain, however, that the horizontal distance at which a submarine boat would be safe is very much smaller than one imagines from the general effect dynamite has against ships. If a dynamite charge is exploded 50 or 60 feet out, the effect upon a ship would be very slight; I believe you have to get so near that this angle of effect in water strikes the ship almost directly upwards, or at very short distances horizontally, otherwise the effect would be very small. But I say this, if the Whitehead when carried by my boats cannot pierce a net, I should be as bad in this respect as the Service boat, but not worse. I should think the trials as suggested by His Royal Highness could very well be made. You can enclose animals in something which has exactly the same strength as my submarine boat, then fire your torpedo at 100 yards and see the effect upon them. You can in that way very easily find out at what distance the torpedo would be dangerous, and then Officers and men would be trained not to run the boat nearer than the limit of distance thus determined. I believe that Professor Abel has already made a number of experiments to determine the strength and direction of the effects of these explosions. I can, of course, make a boat with a very much larger reserve of buoyancy when going down than I have at present. I have the reserve buoyancy very small, in the first place because the boat being thus more sensitive I can control her better; and, in the second place, because whatever buoyancy I have I must have my horizontal propellers strong enough to pull down against it. If I have these propellers much more powerful it means that I consume so much more steam for that purpose than I do now, that is, I diminish the distance for which I can use stored steam to drive my boat, I lose some of the steam in holding myself down that might be used for going forward; but in the 100-foot boat of course there is a tremendous superabundance of steam, and very likely it will be found I can have the horizontal propeller so strong that the safety will be very much increased. Sir

Cooper Key referred to Mr. Scott-Russell's boat. I am very sorry I never heard of it, if I had, I should have mentioned it; but I should say that the form of an inverted open ship of course takes away all possibility of surface speed.

Sir COOPER KEY: It was simply a large diving bell.

Mr. NORDENFELT: It takes away the possibility of living in a bad sea in hard weather, and also the possibility, which I look upon as a most important matter, of being able to run 100 miles or so in a night previous to the attack. It brings the question back to what Admiral Arthur said was the old idea, to have something which went down and did its work, without actually providing a means of running a long distance before that time. I believe that in making use of submarine boats to replace surface torpedo-boats, the long previous surface run is absolutely necessary; you cannot do without it. I fully admit the value of Sir Cooper Key's prediction, that I shall soon give much greater surface speed to this class of boat. The two boats now building will give fully 12 knots per hour, and if, as General Steward proposes, these boats are used to move and to fight "awash," and are not to submerge entirely, except for the purpose of safety if detected, I am quite prepared to lengthen the boats to 130 or 140 feet, and to give them 17 knots surface speed, when the small cupola would run very little chance of being hit. About the speed below I cannot be wrong; anyhow, it can easily be found out. I have not made any real under-water speed trials, and I do not mean to do so. I do not think it is fair to call upon my civilian employes to make trials, the risk of which I cannot previously ascertain; that will be done safely by degrees by some naval Power who can afford such trials. Admiral Arthur mentioned that the boat will be very useful when she runs awash, and he went still further and said probably she would never be used otherwise. I should like nothing better than that the boat should be used awash; I mentioned in my lecture she would be very often so used, but I still feel that if I had come before you and said only, "I have a boat which shows very little above the surface compared to other boats," you might not have come to listen to me, whereas, when I discuss a boat that actually has gone below, you are good enough to come. I also feel that although a good deal of work will be done awash, still if, as I believe, when an enemy comes too near me, if I am not in a position to attack him, it is a very important fact that I can go down 15 or 20 feet, and lie at the bottom in shallow water until it gets dark, and then come up again. In the large boats the men can live about 10 or 12 hours without outside air. In carrying Admiral Arthur's idea a step further, and in looking to the probability of some of these boats being used exclusively as surface boats, with only a small portion of their turtle-backs showing out of water, I can easily see how extremely useful they would be as scouts. With their smoke blown out under water as I do already now, and with 15 to 17 knots speed, they would be the very best and safest scouts that can be constructed—they would fulfil a great want for keeping the touch of the enemy, report its movements, and generally act in supplying news to the Naval Intelligence Department in the flagship. This is a most important service for which secrecy of movement is of great value, and which cannot be done as safely or as well either by launches or by the surface scouts, whose chimneys and smoke reveal their existence and movements at very long distances. I believe Admiral Boys asked a question about the depth of water; what I would propose would be this: the Captain ought to know the depth of water, and if it is more than 30 or 40 feet, he will have to watch carefully the security-regulator. If the depth is not so great, he need not watch it at all. You can go clean down and not stop till you get to the bottom; then of course you cannot advance because of the friction of the bottom, but you have always full control over the boat. I hold very strongly against the old idea of getting so near a ship as to go under it, or letting go anything that floats up to its bottom, or endeavouring to project anything at a short distance, with the idea that it should affix itself to the ship. It is all very well with a wooden ship if you can screw a wire into it, but not with an ironclad. It would bring in such a tremendous factor of uncertainty, that I would not like to take it up at all. As to the light, we have never been down more than 16 feet, but at that depth there is plenty of light from the surface of the water. The mirror of the surface throws a very strong light inside the boat. You cannot see fore and aft except at the angle, at which the water above you, acting as

a lens, reflects objects on the surface. What that angle is I have not ascertained absolutely, but it is a tolerably large angle. You cannot see far forward at all, and you cannot see far astern, it is as black as ink, you can only see a sort of segment. You cannot see forwards, that means that you cannot safely advance at great speed under water, that holds at least until it has been proved to the contrary. It is impossible to think of a submarine boat as a boat that actually manoeuvres and does its work under water; I gave that up from the very commencement. I do not believe for a moment that a man can go down and steer about for great distances, and attack right and left; the risk is too great. He should run awash and then he would see where he was. Off Landskrona it blew like furies and every wave went clean over the cupola. The boat went close round the "Osborne," and between her and the Swedish "Edda," and manoeuvred perfectly, so that there is no trouble in seeing when you are awash; it only requires training. That is the position in which I would like to move about and do the work, and not till I was so near that I could be seen, would I go down. Of course, I would not attack in brilliant daylight, and I would not attack quite alone; I would send some boats on the other side of the ship, or do something else to create a diversion. I do not admit that I can only attack a ship that lies still, because as I can move awash at fully 12 knots with my large boats, I can follow up the movements of any number of ships blockading or bombarding. I do not believe that any squadron afloat ever manoeuvres under fire faster than 6 or 8 knots when blockading or bombarding; at any rate I am not tied to attack only stationary ships. Then about discharging the torpedo; there are the tubes, one above the other.

Admiral FREMANTLE: Is the torpedo protected?

Mr. NORDENFELT: Oh, yes, in regular tubes. There are two ways of doing it. With the small torpedo, and the mode I have indicated of attacking, I always mean to be nearly abreast when I discharge, crawling forwards; when I do fire I am practically still. I therefore have a number of openings, especially towards the rear part of the tube, which let in water. There is water in constant communication with the screw of the Whitehead, and therefore I require no propelling power, other than its own screw, for discharging the Whitehead. It has been proved by the French Government that Whiteheads can discharge themselves out of tubes if water is provided, even at a resistance of $7\frac{1}{2}$ to 8 knots speed. As I never imagine that I should fire at speed under water in that boat, I discharge it simply by her own screws. Also in the larger boat I propose to discharge them simply by their own screws, but there is no reason why I should not apply steam for discharging, not letting the steam act directly upon the Whitehead—because I would lose so much steam by the condensation—but by acting upon pistons which press upon water and the water to drive the torpedo out of the tube. That is, however, a complication which at the present time I have not thought necessary to use.

Admiral BOYS: How do you propose that the crew shall get air?

Mr. NORDENFELT: We had at Stockholm four men absolutely locked up for six hours.

Admiral BOYS: Where do you get the air?

Mr. NORDENFELT: In the boat. The actual cubic space in the small boat is sufficient for four men for six hours, and not only enough for six hours, but you could not measure the diminution of the length of the flame of a tallow dip that was down at the bottom of the floor, whereas the men are higher up where there is less carbonic acid and less impurity in the air. I hope that with the interest which has been shown in these boats—three of which have been already purchased from me—we shall be able to bring to bear upon the subject the intelligence and great experience of naval Officers, and by that means get over a great many smaller points that I feel can be easily settled by lengthened experience. When that is done I believe the boat will be very much better appreciated than I as a mechanic can possibly make it in its early stage.

The CHAIRMAN: Your Royal Highness and gentlemen, it is past the usual hour at which these meetings close, and even if I felt inclined, I should not detain you by any remarks of mine. I had the opportunity of seeing this boat on the Swedish coast, and of being present at the trials. I have also had to report to the Government the result of these investigations, and without saying whether that

report was favourable or not, I will only say from the criticisms that have passed—especially from the distinguished naval Officers who have addressed this meeting—that if my report has been a favourable one I have not erred in their opinion. I think the highest compliment which I can possibly imagine to Mr. Nordenfelt and to this invention was the criticism which we heard from the most distinguished scientific authority in the Navy of the present day—I mean Sir Cooper Key, who apparently entirely accepted the practicability, the security, and safety of this vessel, and whose criticism was limited to the question of speed. I think that shows that evidently, as far as practicability for warfare is concerned, this submarine boat is pretty well accepted by the profession. The only other observation which occurs to me is this. I do not myself attach such very great importance to this invention as a powerful means of submarine defence in English waters. I believe we have a great deal to learn in this vessel with reference to overcoming tidal currents and currents when submerged. In smooth calm waters where there is an absence of tide and current, I believe it is a very formidable machine, and although General Hardinge Steward alluded to the facility with which this vessel was seen in a glassy sea, I can only say that when there was the slightest ripple on the water at distances of 200, 300, and 400 yards, it was very difficult to distinguish. Therefore, as a craft not altogether wholly submerged, but just a boat awash for coast defence and also for the attack of ships at sea, and especially in heavy weather when the fast torpedo-boat cannot act, I believe this vessel will be found of great practical and reliable service. I will not detain you longer, but will ask you to give me permission to convey our best thanks to Mr. Nordenfelt for his very interesting lecture.